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J21404-001

Panchenko J.F., Panchenko D.A., Khafizova E.N.

INFLUENCE OF HOLLOWS SIZE ON THERMO TECHNICAL EFFICIENCY OF WALL MATERIALS

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Abstract. The paper considers the influence of the hollows size in wall materials on their thermo technical efficiency on the example of calcium silicate brick (sand-lime brick).

Keywords. Hollows, air layer, heat conductivity, convection, calcium silicate brick, sand-lime brick, hollow brick.

As is well known the walls materials must meet not only the requirements for strength and durability but also for the thermal properties. The main characteristic of the thermal insulation properties of the material is its thermal-conductivity coefficient, which generally depends on the porosity. Reduction of the thermal-conductivity coefficient with increasing porosity due to the fact that the air- filled pores of the material and air thermal conductivity is very small and can reach 0,021 W/m •ºC. This led to the idea of replacement enclosing parts of the building materials with air layer rather to the creation of enclosing parts, which is made of two walls with an air layer between them or creating special small sized hollows in the wall materials, such as ceramic or calcium silicate (sand-lime) brick, claydite concrete blocks, wood fiber concrete blocks, etc. [1]. A large variety of configurations, sizes and shapes of hollows leads to the question: "What kind of hollows more thermo technical effective?"

It is known experience of enclosing parts with large air layers and hollow stones with large hollows (such as stone "Toronto") without infilling, but thermo technical properties of the walls have been extremely low. To remedy this a layer of air had to fill with wood chips. On the other hand the use of materials in the enclosing parts with several air layers of small thickness (for example, stones type «Crestyanin», ceramic hollow stones) improves the walls' thermal properties compared with the solid walls of the same thickness [2]. Creating materials, applied as a thin coating on the inner surface of the enclosing parts and containing a large number of closed hollow microspheres filled with air, can significantly improve the heat-transfer resistance of external walls [3].

All of this suggests that the heat transfer by air layer occurs differently than in solid and granular materials. In the solid material heat transfer occurs only by thermal conduction, in the air space must be added the heat transfer by convection and radiation.

Thus, if the total amount of heat passing through 1 m^2 of the vertical air layer during 1 hour denote as Q_{total}, it is possible to write (1):

$$Q_{total} = Q_t + Q_к + Q_l \quad (1)$$

where Q_t - the amount of heat transferred by the thermal conductive, W/m^2 • h;
Qk - amount of heat transferred by convection, W/m^2 • h;

Q_l - the amount of heat transferred by radiation, W/m^2 • h

Transfer of heat conduction obeys the heat transfer law in the solid material, therefore (2):

$$Q_t = (\tau_1 - \tau_2)\frac{\lambda_t}{\delta} \tag{2}$$

where τ_1 and τ_2 - temperatures on the opposite surfaces of the air layer;

λt - thermal conductivity coefficient of still air;

δ - thickness of the layer, m.

Air convection in the layer comes about from the temperature differences on the surfaces, and it has the character of a natural convection. Air near the surface with higher temperature is heated and moves from the bottom upward direction, while air near the cold surface cools down. On the analogy of formula (2) for the amount of heat transferred by convection, one can write (3):

$$Q_\kappa = (\tau_1 - \tau_2)\frac{\lambda_\kappa}{\delta} \tag{3}$$

where λ_k-conditioned factor called the heat transfer by convection.

Unlike conventional thermal conductivity coefficient of this ratio is not constant, but depends on the layer thickness, the air temperature in the layer, the temperature difference on the surfaces layer and the place of layer in the wall [2].

The values of the coefficients $\lambda_T + \lambda_k$ of the vertical layers are given in table 6 [2] depending on the thickness of the interlayer δ and the temperature difference between its surfaces τ_1-τ_2. Convection heat transfer coefficient increases with increasing thickness of the interlayer. This increase is explained by the fact that thin layers of ascending and descending air currents mutually diffuse and value λ_k becomes zero in very thin interlayers (less than 5 mm). With increasing thickness of the interlayer, on the contrary, air currents convection becomes more intense, increasing the value of λ_k. The value λ_k increases with increasing temperature difference on the surfaces of the layer due to increase the intensity of convection currents in the interlayer.

In addition to transferring heat conduction and convection in the air space occurs more direct radiation between surfaces limiting the air layer. Heat quantity Q_l transmitted in the air layer by the radiation from surface with a high temperature τ_1 to the surface with lower temperature τ_2, can be expressed such as previous expressions (4):

$$Q_l = (\tau_1 - \tau_2)\alpha_l \tag{4}$$

where α_l - radiation heat transfer coefficient defined by the formula (5):

$$\alpha_l = \frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_0}} \frac{\left(\frac{\tau_1+273}{100}\right)^4 - \left(\frac{\tau_2+273}{100}\right)^4}{\tau_1 - \tau_2} \tag{5}$$

where C_1 and C_2 - radiation coefficient of surfaces, which is for the calcium silicate brick (sand-lime brick) is equal to 4,5; C_0 - radiation coefficient of absolutely blackbody, which is equal to 5,67.

The value $\frac{(\frac{\tau_1+273}{100})^4-(\frac{\tau_2+273}{100})^4}{\tau_1-\tau_2}$ placed in the right part of the formula (5) and called "temperature coefficient" depends on the average air temperature in the air layer and is defined by the table 7 [2].

If we add up the values $Q_t+Q_к+l_л=Q_{total}$ we can obtain (6):

$$Q = (\tau_1 - \tau_2)\frac{\lambda_t+\lambda_к+l\delta}{\delta} \tag{6}$$

Expression $\lambda_к + \lambda_t + \alpha_l\delta$can be regarded as the thermal conductivity coefficient of air in the layer, obeying laws of heat transfer through solid materials. This is called total factor "equivalent thermal conductivity coefficient of the air layer" λ_e. Thus we have (7):

$$\lambda_в = t + \lambda_к + \alpha_l\delta \tag{7}$$

Knowing the equivalent thermal conductivity coefficient of air in the layer, its thermal resistance is determined in the same manner as for the layers of solid or granular materials, that is

R = δ / λe [2].

Let’s consider the effect of the size of the hollows on the air thermal conductivity coefficient as an example of calcium silicate brick (sand-lime brick). Schematic view of a stationary process of heat transfer through the outer enclosing part of calcium silicate brick is shown in Figure 1.

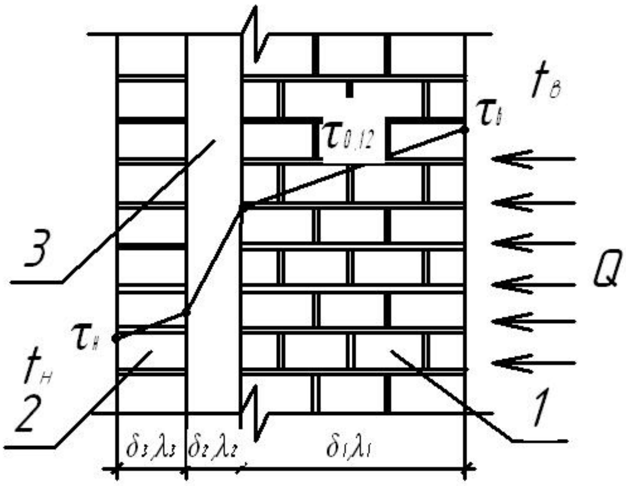

Figure 1 - Scheme of the heat transfer process through the outer enclosing part of calcium silicate brick.

Materials characteristics of enclosing part are shown in Table 1, the nominal case conditions are in Table 2.

Table 1

Materials characteristics of enclosing part

Layer number	Name of the material	Layer thickness, δ, м	Thermal conductivity coefficient, W/m • ºC	Thermal resistance of the material layer, , R, m^2 ºC / W
1	Calcium silicate facing	0,12	0,62	0,19

	thickened hollow brick			
2	Extruded foam polystyrene	0,08	0,03	2,67
3	Calcium silicate thickened hollow common brick	0,38	0,62	0,61

Table2

Nominal case conditions

Characteristics	Units	Value
Inside air temperature, t_v	° C.	+ 20,0
Outside air temperature, tn	° C	- 17,4
The heat transfer coefficient on the inner surface α_v	W/(m^2 • ° C)	8,7
Thermal resistance of the wall, R	m^2 ° C / W	3,47
Resistance to heat transfer wall, R_0	m^2 ° C / W	3,63
Resistance to heat absorption, R_v	m^2 ° C / W	0,115

To define the value $\lambda_T + \lambda_K$, in formula (7), it is necessary to know the temperatures on the surfaces of hollows, which are determined on the temperature distribution in the structure. Formula (8) serves for determining the temperature of the inner surface of the structure. Formula (9) can define the temperature of each layer.

$$\tau_в = t_в - \frac{t_в - t_n}{R_0} R_в \tag{8}$$

$$\tau_n = t_в - \frac{t_в - t_n}{R_0} \left(R_в + \textstyle\sum_{n-1} R\right) \tag{9}$$

where τ_n - temperature on the inner surface of the n-layer of the enclosing part, considering number of layers from the inner surface; R - the sum of thermal resistances of the first n-1 layers of the structure.

Thus, $\tau_в$=+16,9, $\tau_{0,12}$=+12,5ºC.

Let's consider two sizes of hollows in the calcium silicate brick, while maintaining the overall hollowness (Figure 2):

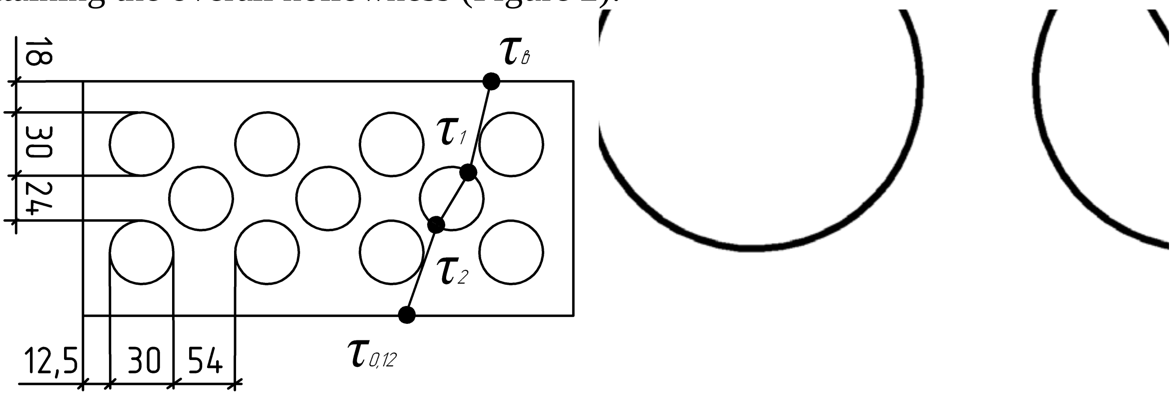

Figure 2 Variation of the calcium silicate brick hollowness

The calculation data of the temperature distribution in the brick are shown in Table 3, the thermal characteristics of brick with different hollows are in Table 4.

Table 3

Temperature distribution in the calcium silicate brick with different hollows

Temperature	Variation of the brick hollowness	
	11 hollows	3 hollows
τ_B, °C	+18,8	+18,8
τ_1, °C	+18,3	+18,4
τ_2, °C	+17,4	+17,3
$\tau_{0,12}$, °C	+16,9	+16,9

Table 4

Influence of the hollowness nature on the thermo technical properties of brick

Characteristics	Variation of the brick hollowness	
	11 hollows	3 hollows
The temperature difference on the surfaces of the hollows (τ_1-τ_2), ° C	0,9	1,1
Factor considering the heat transfer by convection and conduction, $\lambda_1 + \lambda_2$, ° C.	0,024	0,052
The average air temperature in the air layer, $\frac{(\tau 1-\tau 2)}{2}$, ° C	17,9	17,9
Temperature coefficient	0,98	0,98
The coefficient of heat transfer by radiation, α_l, W / (m2 • ° C)	1,58	1,58
Equivalent air thermal conductivity in the air layer, λ_e, W / m • ° C	0,071	0,137
Thermal resistance of the layer	0,42	0,39
Reduced thermal resistance of the brick	0,27	0,20
Thermal conductivity coefficient of brick, λ_k, W / m • ° C	0,45	0,59

Thus, considering all the laws of heat transfer, it becomes clear that the most effective thermo technical point of view is eleven hollowed brick compared to the brick with three hollows, its thermal conductivity coefficient below 16%.

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J21404-002

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INFLUENCE OF COARSE ON FOR A LONG STRENGTH OF CLAY SOILS IN CUTOFF

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Introduction*. When geotechnical studies for the construction of buildings and structures on eluvial soils widespread in the territory of the Republic of Kazakhstan, is often necessary to determine the mechanical characteristics of clay soils with COARSE inclusions [1]. Despite the considerable amount of the research, the patterns of their strength has not yet been studied adequately. This applies mainly to data on the rheological properties of soils, in particular, on the impact of the content of rock inclusions, their size, shape, mutual arrangement, as well as mechanical features and inclusions on aggregate characteristics of their long-term strength. The aim is to study the effect of inclusion content on the parameters of long-term strength of the soil at a cut.*

Keywords: coarse soil, clay aggregate, long-term strength, inclusion content, slice.

Methodology and experimental program. Experiments were performed in shear device on artificial mixtures of clay and gravel inclusions and chalk. In preparing the samples ranged inclusion content $n = 0 - 0{,}5$, the strength of the inclusions (gravel, chalk), d= particle size of 0 - 8 mm, the initial moisture content clay. After the destruction of the sample surface shear tests were made to re- shift (like " die die for ") to determine the residual strength of soils.

To determine the mechanical properties of the inclusions (chalk, gravel) ispolzovalist modern electronic devices «NDT ONYX 2.5», «1.0 PULSAR». Preparing for the experiments carried out as follows. In the camera device was packed layers fragmental - clay mixture. During the tests carried out photographic images of ground structure before and after a predetermined cutoff surface.

Methods of determining the long-term strength fragmental -clayey soils. Determination of parameters of long-term strength of soils was carried out by the procedure [2] c using the data sample testing stages tangential stress τ and fixing horizontal displacement Δl for equal time intervals Δt, followed by the construction of graphs in a coordinate system $\ln\tau - \ln\Delta 1$(Fig. 1).

Typical results of such constructions are shown in Fig. 2.

Limit value long-term strength of soils τ ∞, defined by the points of inflexion ln $\tau = f(\ln\Delta 1)$, and their numerical values were calculated from the relation [2] $\tau\infty = k\tau\, t$ (k=0,7-0,9). Along with the procedure laid down analyzed the experimental data for the rapid application of the load circuit.

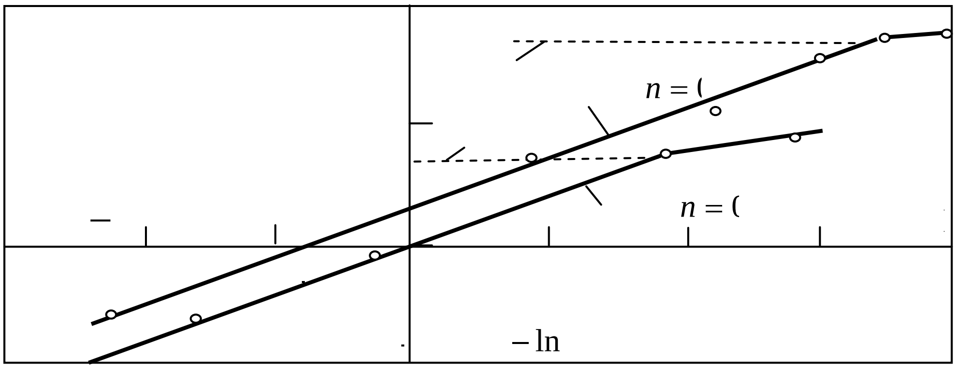
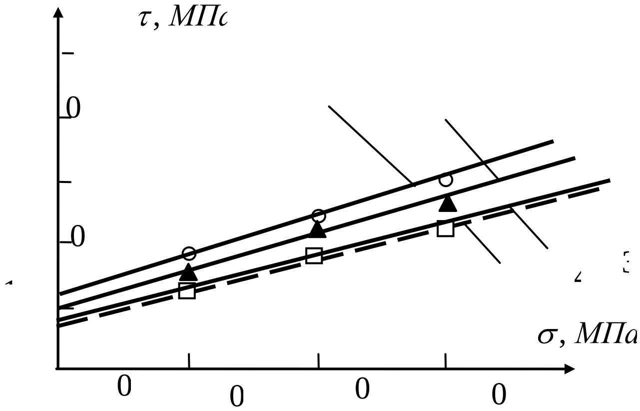


Fig. 1. Dependencies ln τ= f (ln Δl)

Analysis of data from the study of long-term strength of the clay filler. This series included experiments with conditionally instantaneous application load (load speed 0.025 MPa / min), application load at a rate of 0.025 MPa / h, determining the residual soil shear strength (shear tests on the destroyed cut surface). Specific details of the experiments are shown in Fig. 2.



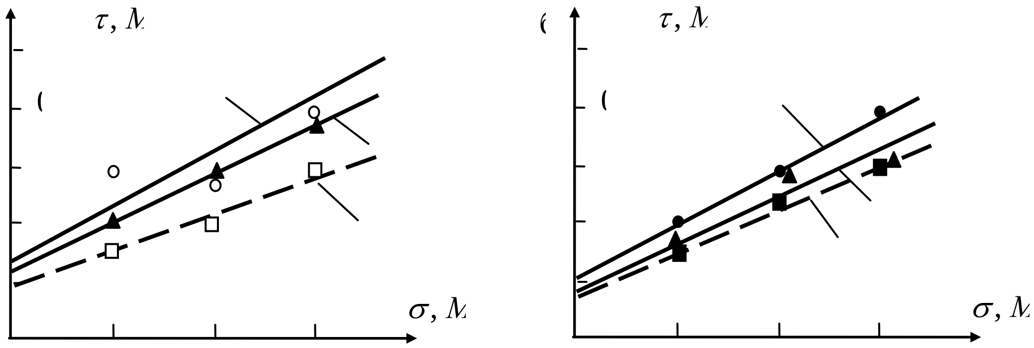
1 - shareware - instant slice; 2 - slice with a speed of 0.025 MPa / hour;
3 - extremely long durability; 4 - residual strength

Fig. 2 Dependencies $\tau = f(\sigma)$ **for clay aggregate**

These data indicate that the strength characteristics of the clay substantially depend on the rate of load application. Their feature is practical compliance data obtained on residual values and ultimately long-term strength of clay soil shear.

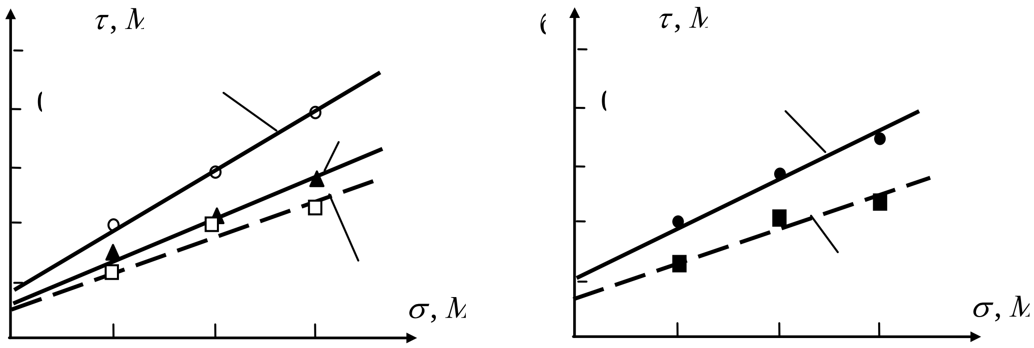
Assessing the impact of loading rate on the long-term strength fragmental - clayey soils. Fig. 3 shows typical data on the effect of shear load application rate on the strength of fragmental -clayey soils in the slice. The data obtained show that the manifestation of the rheological properties in the core may affect the strength values of clayey soils containing coarse inclusions.

Effect of inclusions on the long-term strength of soils. Generalized data on the impact of the inclusion content are shown in Fig. 4. Numerals are numbers of experiments with the content of the inclusions. Analysis of experiments show that with the increase of coarse inclusions from 30 to 50% increase in fixed angle of internal friction, there is also a change in the clutch ground.



a - inclusion of chalk n= 0,5; b - the inclusion of pebbles n= 0,3;
1 - shareware snapshot of; 2 - slice with a speed of 0.025 MPa / hour;
3 - residual strength

Fig. 3. Influence of loading rate on the strength of soil

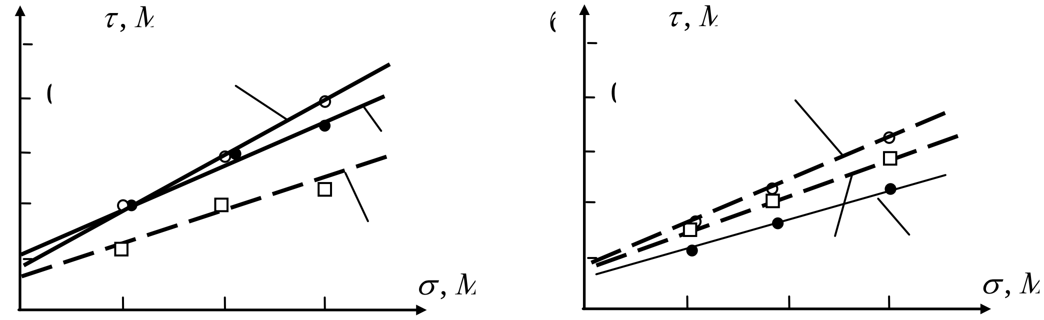


a - inclusion of pebbles; b - the inclusion of chalk;
1 - inclusion content 50%; 2 - inclusions content of 30%;
3 - experiments without inclusions

Fig. 4. Effect of inclusions on the strength of the soil

Effect of inclusions on the strength of soil shear resistance. To assess the impact of this factor on the strength of soil at a cut a series of experiments with inclusions of pebbles and less durable material - chalk. Typical results are shown in Fig. 5. Their analysis shows that the strength of the inclusions affect the resistance of the soil shear. Recorded a slight decline angle of internal friction and a slight increase in the proportion of soil adhesion with decreasing strength of coarse inclusions. A similar pattern was noted for the residual strength of the soil.

Effect size inclusions on long-term strength of soils. To investigate the influence of this factor on the strength of soils conducted a series of experiments with the size of the inclusions 4 mm, 8 mm and 4-8 mm mixed content of pebbles and chalk. Data from these experiments are shown in Fig. 6. They imply that the size of the inclusions of pebbly material has certain influence on the resistance of the soil shear. There has been some reduction in the angle of internal friction and the specific coupling with decreasing particle size of the inclusions (Fig. 6a). At the same time for the inclusions of chalk this effect is virtually absent (Fig. 6b).



a - data on long-term strength at n=0,5; b - Data on the residual strength at n=0,5;
1 - containing impurities of pebbles with n=0,5; 2 - inclusions with a content of chalk when n=0,5; 3 - experiments without inclusions

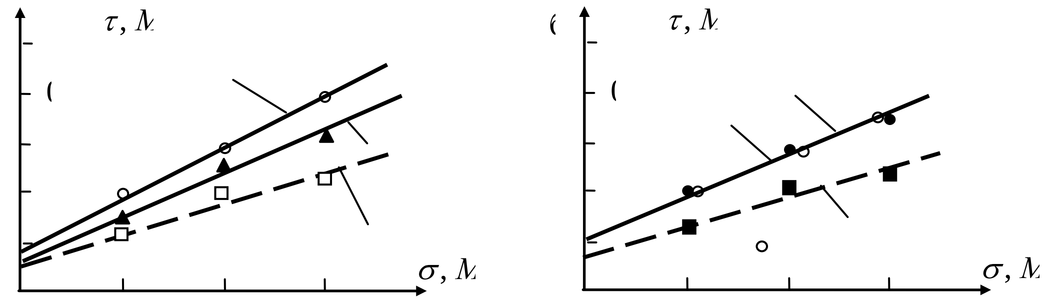
Fig. 5. Influence of inclusions on the strength of soil shear resistance

Influence of humidity on the strength of soil aggregate. Typical results of experiments evaluating the effect of moisture filler (clay) on the strength of fragmental-clay mixtures are shown in Fig. 7.

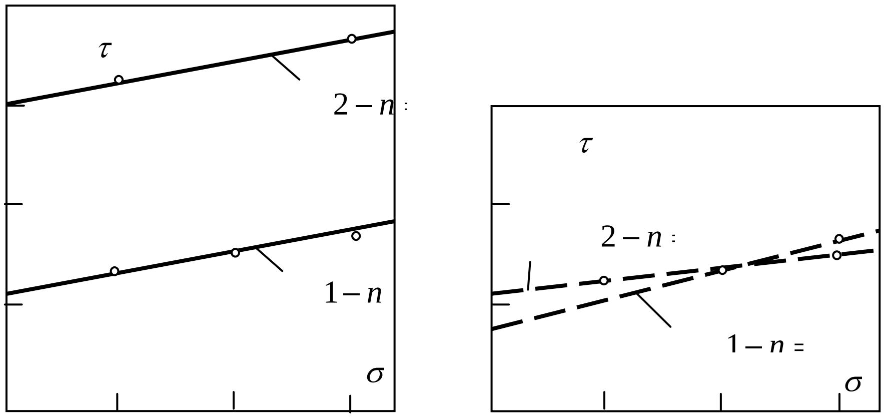
Data analysis showed that the increase in aggregate moisture leads to a decrease of its total shear resistance. According to the results of data processing, the following values of strength parameters of soils:

- For the initial soil moisture : φ=140 (n=0,3); C=0,11 MPa (n=0,3);
- For soil dried : φ=10,60 (n=0,3); With 0.29 MPa (n=0,3);
- Residual strength for the original soil : φ=140 (n=0,3), C=0.081 MPa (n=0,3);
- Residual strength for the dried soil (n=0,3); φ=7,10; G=0.11 MPa.

These data suggest that the magnitude of the angle of internal friction varies little for peak performance and residual strength. At the same time, the values for specific cohesion indicators and peak residual strength are significantly different.



a - the inclusion of pebbles; b - the inclusion of chalk; 1 - containing 50% of inclusions and inclusions of size 8 mm; 2 - inclusions with a content of 50% and a mixed grain size 4-8 mm inclusions; 3 - experiments without inclusions**Fig. 6. Influence of particle size on the strength of soil inclusions**



a - shift samples of the original structure; b - shift damaged surface;
1 - initial moisture content; 2 - after drying
Fig. 7. Dependencies soil shear resistance against humidity

Conclusion

The studies have shown that long-term strength parameters fragmental-clayey soils depend on the content of coarse inclusions, their size, strength, and the state of the aggregate of the clay soil.

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